EV Charging Stations and Modes: International Standards

Maria Carmen Falvo, Danilo Sbordone
DIAEE, Electrical Engineering
University of Rome Sapienza
Rome, Italy
Emails: {mariacarmen.falvo, danilo.sbordone}@uniroma1.it

I. Safak Bayram, Michael Devetsikiotis
Department of Electrical and Computer Engineering
NC State University
Raleigh, NC
Emails: {isbayram, mdevets}@ncsu.edu

***Abstract*— In recent years, Electric vehicles (EVs) are receiving significant attention as an environmental-sustainable and cost-effective substitute of vehicles with internal combustion engine, for the solution of the dependence from fossil fuels and for the saving of Green-House Gasses emission The present paper deals with an overview on different types of EVs charging stations and a comparison between the related European and American Standards. The work includes also a summary on possible types of Energy Storage Systems (ESSs), that are important for the integration of EVs fast charging stations of the last generation in smart grids. Finally a brief analysis on the possible electrical layout for the ESS integration in EVs charging system, proposed in literature, is reported.**

Keywords*— *Electric Vehicles, Energy Storage, ICT, International Standards, Smart Grid.

I. Introduction

In recent years, Electric vehicles (EV) are receiving significant attention as an environmental-sustainable and cost-effective substitute of vehicles with internal combustion engine (ICE), for the solution of the dependence from fossil fuels and for the saving of Green-House Gasses (GHG) emission [1]-[5]. In this framework, different standards for EVs charging systems have been explored by several organizations around the world. For defining them, organizations consider the safety, the reliability, the durability, the rated power and the cost of the different charging methods.

The charging equipment for EVs plays a critical role in their development, grid integration and daily use: a charging station generally includes charge cord, charge stand, attachment plug, power outlet and vehicle connector and protection system. The configuration of the charging station can vary from Country to Country depending on frequency, voltage, electrical grid connection and standards. In any case, charging time and lifetime of an EV's battery are linked to the characteristics of the charger that first must guarantee a suitable charge of the battery. Then a good charger should be efficient and reliable, with high power density, low cost and low volume and weight.

The charger power level is the main parameter that has an influence on charging time, cost, equipment and effect on the grid. For this reasons the International Standard in North America and Europe are referred to this parameter for the EV charging equipment classification. Besides, the EV charging system, that can be categorized into off-board and on-board types with unidirectional or bidirectional power flow:

- a unidirectional charging limits hardware requirements and simplifies interconnection issues;
- a bidirectional charging supports battery energy injection back to the grid.

A charger located inside the vehicle allows owners to charge their vehicles everywhere a suitable power source is available. Nonetheless on-board chargers usually have limited power due to their weight, space need and costs. They can be integrated with the electric drive for avoiding these problems. The availability of a charging infrastructure reduces on-board energy storage requirements and costs. An off-board charger can be designed for high charging rates and is less constrained by size and weight.

The present paper deals with an overview on different type of EVs charging stations, making a comparison between the European and American Standards. The paper includes also a summary on possible types of Energy Storage Systems (ESSs) and possible layouts of charging stations including them. This aspect is object of many papers in the recent literature. EVs require to the grid during their charging a power as higher as the recharge time want to be short. Therefore, an uncoordinated charging of a huge number of EVs can have a negative impact on the electrical grid operation, in terms of power outages, voltage fluctuations, harmonics pollution and so on. The implementation of EVs charging strategy, through an aggregation agent, is strictly related to a deployment of smart-grid technologies, such as smart meters, ICT and ESSs. The ESSs can become fundamental for the integration in smart grids of EV fast charging stations of the last generation: the storage can have peak shaving and power quality functions and also to make the charge time shorter [6]-[12].

II. EVs Charging Stations

A. European Standards and trend

European electricity companies, particularly distribution system operators (DSOs), are investing in the necessary

infrastructure to stand-in a single European market for EV. European standards are indispensable to safeguard that drivers enjoy convenient EU-wide charging solutions that avoids a multiplicity of cables and adaptors and so retrofit costs. In June 2000, the European Commission issued a standardization mandate to the European standardization bodies CEN, CENELEC and ETSI (M/468) concerning the charging of EVs. The mandate stressed the need for interoperable plugs and charger systems to promote the internal market for EV and to discourage the imposition of market barriers. The Focus Group set up to respond to M/468 delivered a comprehensive and valuable report. However, given that the mandate objective was to achieve interoperability, not the adoption of a single connector, no recommendation has been made with regards to the choice of the AC mains connector. As a consequence, two types of connectors have been assessed as appropriate for the European situation. The choice between them is left to the market and will depend on the different National regulatory frameworks. Today the only standards available at European level, dealing with the charging system, plugs and sockets, are contained in the IEC 61851 [13]-[14]. The actual standards provide a first classification of the type of charger in function of its rated power and so of the time of recharge, defining three categories here listed:

- Normal power or slow charging, with a rated power inferior to 3,7 kW, used for domestic application or for long-time EV parking;
- Medium power or quick charging, with a rated power from 3,7 to a 22 kW, used for private and public EV;
- High power or fast charging with a rated power superior to 22 kW, used for public EV.

In function of the amount of power, different main connections are possible and they are summarized in terms of electrical ratings in Table I:

TABLE I
ELECTRICAL RATINGS OF DIFFERENT EVS CHARGE METHODS IN EUROPE

Charge Method	**Connection**	**Power [kW]**	**Max current [A]**	**Location**
Normal power	1-Phase AC connection	3,7	10-16	Domestic
Medium power	1- or 3-phase AC connection	3,7 - 22	16-32	Semi-Public
High power	3-phase AC connection	> 22	> 32	Public
High power	DC connection	> 22	> 3,225	Public

The IEC 61851-1 Committee on “Electric vehicle conductive charging system” has then defined 4 Modes of charging, concerning:

- the type of power received by the EV (DC, single-phase or three-phase AC),
- the level of voltage (for AC in range between single-phase 110V to three-phase 480V),
- the presence or absence of grounding and of control lines to allow a mono or two-way dialogue between the charging station and EV,
- the presence and location of a device protection.

The 4 Modes are briefly described below and shown in Fig. 1:

- Mode 1: slow charging from a household-type socket-outlet in AC,
- Mode 2: slow charging from a household-type socket-outlet with an in-cable protection device in AC,
- Mode 3: slow or fast charging using a specific EV socket-outlet with control and protection function installed in AC,
- Mode 4: fast charging using an external charger in DC.

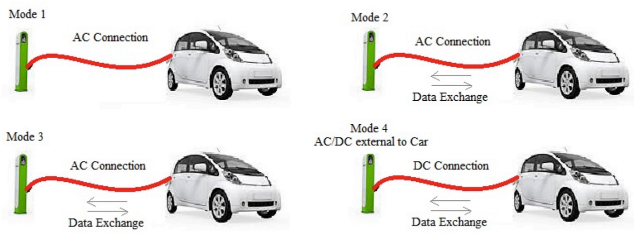


Fig. 1. IEC 61851-1 charging modes.

For the Mode 1 (fast charging) in DC two sub-modes of operation are then considered: DC Level 1 (voltage inferior to 500 V, current inferior to 80 A, power at 40 kW); DC Level 2 (voltage inferior to 500 V, current inferior to 200 A, power at 100 kW).

The same committee has defined three types of socket-outlets:

1. IEC 62196-2 "Type 1" - single phase vehicle coupler - reflecting the SAE J1772/2009 automotive plug specifications – Yazaki;
2. IEC 62196-2 "Type 2" - single and three phase vehicle coupler - reflecting the VDE-AR-E 2623-2-2 plug specifications – Mennekes;
3. IEC 62196-2 "Type 3" - single and three phase vehicle coupler with shutters - reflecting the EV Plug Alliance proposal – SCAME.

All modern plug-ins, except for mode 1, permit communication with the charge station. In the recent years, the Society of Automotive Engineers (SAE) has recognized another type of connector for EV: the Combo Connector (o Combo 2) J1772 that is able to combine the fast charge Mode 4 in DC (Level 1 and 2) with the slow/fast charge Mode 3 in AC in a single unit.

The actual situation in Europe in terms of application of charging Mode and type of plug are summarized in TABLE II.

TABLE II
ACTUAL MODE AND TYPE OF PLUGS FOR EVS CHARGER IN EUROPE

	Private domestic socket	**Private dedicated E-mobility socket**	**Semi-Public AC**	**Public AC**	**Public DC**
Power connection	≤ 3,0 kW/ ≤ 3,7 kW 1-phase AC	Up to 22 kW	Up to 22 kW	Up to 22 kW	50 kW (ChadeMo)
Plug (Infrastructure side)	Domestic	IEC 60309-25 Type 2/ Type 3	Type 2/ Type 3	Type 2/ Type 3	Yazaki (ChadeMo)
Charging mode	Mode 2	Mode 2 Mode 3	Mode 2 Mode 3	Mode 2 Mode 3	Mode 4

Recognising that there is a need to offer customers a high-power charging possibility that allows them to recharge the EV battery within a limited timeframe, only the high power connection would satisfy this aim. Two technologies are at hand for high-power charging: DC off-board charging or AC on-board charging.

DC off-board charging is more common today, due to the introduction of the first generation of Japanese electric cars on the European automotive market. Nevertheless, European automotive manufacturers have expressed their intention to promote EV with an on-board charger, which would be compatible with a high-power range AC supply arrangement. For the DC connection, a Japanese socket (CHAdeMO protocol), with a maximum power level of 50 kW, is currently the only available product on the market and is thus being rolled out in several European countries although it is not internationally standardised yet [15].

The European Automotive Industry is however promoting the combined charging system with the Combo connector, which features a single inlet for AC and DC charging on the side of the EV and can potentially deliver high-power charging of up to 100 kW in future. The Combo connector is currently under development and going through the IEC standardisation process.

The European Commission has decided that all electric vehicles must have installed the "Type 2" connector, showed in Fig. 2. This should resolve a central problem regarding EV charging stations: lack of interoperability.

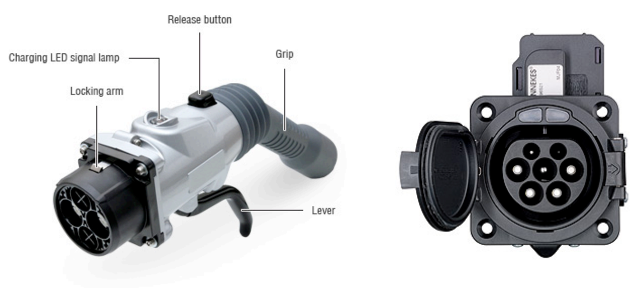


Fig. 2. CHAdeMO (on the left) and "Type 2"connectors

This connector can also be used in three-phase 400 V, having seven contacts in total. Type 2 connector can reach enough high values of charging power: up to 43 kW with fixed cable (63A/400V), up to 22 kW with detachable cable (32A/400V).

The technological choice between on- or off-board chargers will be determined by what suits the EV on the market and the relative cost of both systems for the infrastructure provider. For the electricity industry, it does not matter much whether the conversion from AC to DC is done on- or off-board. In any case, high-power charging is likely to be a premium-priced service for the electric vehicle driver, the use of which should be encouraged only when charging time is critical, i.e. in the middle of a journey. In such cases, limiting or interrupting charging for load management purposes (except for emergencies) is unlikely to be acceptable to EV customers. For the electricity industry, the limited possibilities of load management therefore make high-power charging less attractive.

B. American Standards and trend

For many years, the Society of Automotive Engineering (SAE) has been working on standard J1772 [15]. Today SAE J1772 in its last version defines EV charging system architecture: it covers the general physical, electrical and performance requirements for the EV charging systems used in North America. In function of the rated power, voltage and current the charging systems for EV in North America are classified into three categories, which are AC Level 1, AC Level 2 and DC Level 3. In particular:

- for Level I, the charger is on-board and provides an AC voltage at 120 or 240 V with a maximum current of 15 A and a maximum power of 3,3 kW;
- for Level II, the charger is on-board and provides an AC voltage at 240 V with a maximum current of 60 A and a maximum power of 14,4 kW;
- for Level III, the charger is off-board, so the charging station provides DC voltage directly to the battery via a DC connector, with a maximum power of 240 kW.

TABLE III summarizes the electrical requirements of the three charging systems in North America.

TABLE III
ELECTRICAL RATINGS OF DIFFERENT CHARGE METHOD IN NORTH AMERICA

Charge Method	**Nominal AC Supply Voltage [V]**	**Maximum Current [A]**	**Maximum Power [kW]**	**Charger Location**
AC Level 1	120	12	1,44	On-board 1-phase
AC Level 2	240	32	7,7	On-board 1 or 3 phase
DC Level 3	208- 600	400	240	Off-board 3-phase

SAE J1772 defines the standardized connector that covers the general physical, electrical, communication protocol and performance requirements for the EV conductive charge system and coupler. The SAE J1772 connector is considered a

"Type 1" implementation of IEC 62196-2 providing a single phase coupler. It is shown in Fig. 3.

In function of the power level of the charger, the time of charging changes and with it the type of use of the charging system. For this reason the three power levels of charging are also classified in low, primary and fast method in function of the charging time.

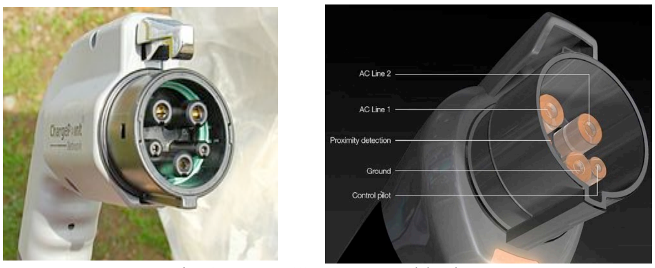


Fig. 3. "Type 1"connector with Pinout

The most common storage technology used for EV application is Li-Ion battery, with energy capacities included between 5 kWh to 53 kWh. Table IV classified the three power levels adopted in North America from the point of view of the charging time and of EV battery energy capacity:

TABLE IV
CHARGING POWER LEVELS, TIMES AND BATTERY TECHNOLOGY

Power Level Types	Typical Use	Power Level [kW]	Charging Time [h]	EV battery energy capacity [kWh]
Level 1 – Low Charge (120 Vac)	Slow charging for home or office	1,4	4–11	5-15
Level 2 – Primary Charge (240 Vac)	Primary charging at private or public use	8	2–6	5-15
Level 3 - Fast Charge (208-600 Vac)	Fast charging for public use	50 or 100	0,4–1 or 0,2–0,5	20–50

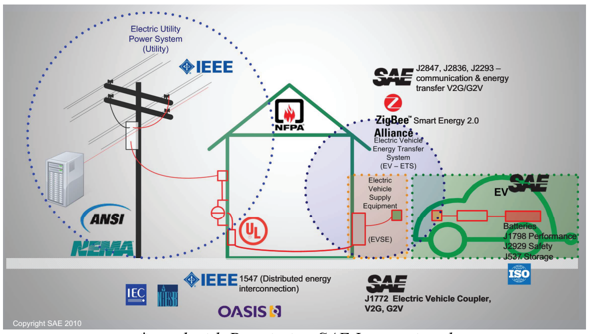
Another classification can be made in terms of type of outlet used in the charging station. The American standards define three types for the three levels:

- Level 1 charging method, the slowest one, uses a standard 120V/15A single-phase grounded outlet, such as NEMA 5-15R. The connection may use a standard J1772 connector into the EV AC port. For home or business sites, no additional infrastructure is necessary;
- Level 2 charging method, the primary one for dedicated private and public facilities, requires dedicated equipment for home or public charging;
- Level 3 charging method, the fastest one and used for commercial application, typically operates with a 480 V or higher three- phase circuit and requires an off-board charger to provide regulated AC-DC conversion.

Standards for DC plugs and hardware are in progress. The Japanese protocol CHAdeMO is gaining international recognition [15].

SAE defines also the communication standards for the EV charging stations. A first group contains the standards and technologies between EV and Electric Vehicle Supply Equipment (EVSE) that is required for energy transfer monitoring and management, billing information, and authorization. The standardization is required for fast adoption of EVs and proper functioning of EV network components. The main standards on communication are presented in Fig. 4 [16]:

- SAE J2993: it covers the required functionalities and system architectures for electric vehicle energy transfer system;
- SAE J2836/1 & J2847/1: it specifies use requirements and use cases for communications between EVs and the power grid, mainly for energy transfer. The main focus is on grid-optimized energy transfer for EVs to make sure that drivers have enough energy while minimizing the stress on the grid;
- SAE J2836/2 & J2847/2: it specifies the requirements and use cases for the communications between EVs and off-board DC charger;
- SAE J2836/3 & J2847/3: it specifies use cases and additional messages energy (DC) transfer from grid to electric vehicle. Also supports requirements for grid-to-vehicle energy transfer;
- SAE J2931: it specifies the digital communication requirements between EV and off-board device.
- SAE J2931/1: it specifies power-line communications for EVs.



** used with Permission SAE International*
Fig. 4. Overview of EV Energy Transfer Standards*

III. ENERGY STORAGE SYSTEMS FOR EV CHARGING STATIONS

One of the major challenges for EV charging stations, especially the public one, is to reduce charging time. As seen in the International standards, this aim can be addressed by increasing the rate of power transfer: the fast charge method corresponds both in Europe and in United States to the maximum value of power (50-100 kW). When a large number of EVs are charged simultaneously, problems may arise from a substantial increase in peak power demand to the grid [18]-[27]. Addressing this peak power requirement may increase the generation cost of the energy, as well as the cost of the distribution and public charging infrastructure. The integration of an Energy Storage System (ESS) in the EV charging station cannot only reduce the charging time, but also reduces the stress on the grid.

A suitable comparison among the various energy storage technologies applicable for this scope is among electrochemical storages (batteries), electromechanical storages (flywheels) and electrostatic storages (ultra-capacitors).

The batteries are electrochemical storages that alternate charge-discharge phases allowing storing or delivering electric energy. The main advantage of such a storage system is high energy density, the main inconvenience is their performance and lifetime degrades after a limited number of charge and discharge cycling. This affects the lifetime for all application (from 100 to 1,000 cycles).

The flywheels are electromechanical energy storage devices, where energy is stored in mechanical form, thanks to the rotor spinning on its axis. The amount of stored energy is proportional to the flywheel moment of inertia and to the square of its rotational speed. The life of flywheels is greater than the batteries (up to 100,000 cycles) and the frequent charging and discharging does not adversely affect their life time. Additionally, flywheels have a power density that is typically a factor of 5 to 10 times greater than batteries. A drawback of the flywheel technology is the time of reply to fast variations of required power: it is also proportional to the inertia of the system, so the gradient of the power in time is generally high.

The ultra-capacitors are electrostatic storage system, characterized by a very high power density, but with a lower energy density than batteries and flywheel. Ultra-caps have also the benefits of charging and discharging much faster than batteries, a longer service life and a higher the efficiency than batteries.

Another important issue in the comparison of these three storage technologies deals with the cost: the installation, maintenance and replacement costs of the batteries make them no so attractive as a feasible solution as stationary energy storage system; the installation cost of a flywheel is usually greater than batteries, but its longer life and simpler maintenance results in a lower total costs.

Finally an important consideration is about the different physical size and weight of the three technologies: for the same amount of energy stored, batteries are more light and small then ultra-capacitors and flywheels.

From this brief analysis, it is clear that a good ESS for the coupling fast EV charging stations can be considered a system including batteries and ultra-capacitors: the first are suitable for their high energy densities and the second for their high power density. In literature, different application of ESSs based on use of batteries and super-caps for the integration with EV charging station are present. Today, the storage technologies really available are summarized in Table V.

Comparing the different types of batteries shown in Table V:

- Pb-Acid batteries, with a life time of 200-300 cycles, have high capacity, low volume energy density, low capital cost, long life time, but on the other hand they are characterized by low efficiency (75%), potential adverse environmental impacts;
- Ni-MH batteries, with a life time of 100-200 cycles, a very high energy density;
- Li-Ion batteries have a very high efficiency (95%) and energy density, and high number of life cycles (3,000-5,000);
- Li-Poly batteries have lower energy density than Li-Ion ones, but they are not flammable as Li-Ion and so offer more safety.
- Ni-Cd batteries have low energy density (40-60 Wh/kg), low efficiency (60%) and suffer of memory effect.

At these technologies it is necessary to add the Sodium-Sulphur (Na-S) batteries that, with a life time of 2,000-3,000 cycles, have a very high energy and power capacity, high energy density, but they are characterized by high production cost and safety concerns, that make them not commercially sustainable at the moment. The most common technology for batteries used for EV application is Li-Ion battery, with energy capacities included between 5 kWh to 53 kWh.

TABLE V
ENERGY STORAGE TECHNOLOGIES

Type	Energy Efficiency [%]	Energy Density [Wh/kg]	Power Density [W/kg]
Batteries Pb-Acid	70-80	20-35	25
Batteries Ni-Cd	60	40-60	140
Batteries Ni-MH	50-80	60-80	220
Batteries Li-ion	85-95	100-200	300-2000
Batteries Li-polymer	80-90	100-200	300-2000
Super-caps	90+	25-75	5,000-20,000

Talking about the integration of ESSs in EVs charging station, another important issue is the way of integration in terms of electrical scheme. Two possibilities are investigated in literature, based on an AC-bus configuration and DC-bus configuration, shown in Fig. 5 [23]-[27].

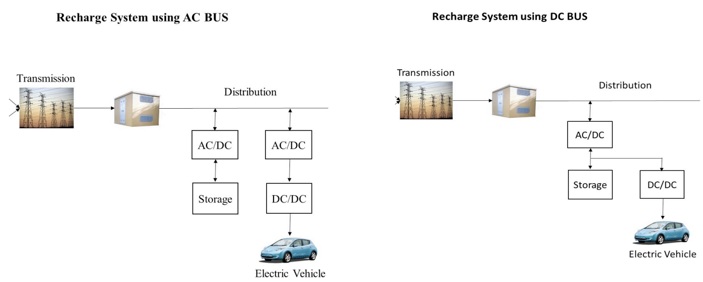


Fig. 5. Scheme for the integration of the ESS with the EV charging station.

The AC-bus scheme is generally preferred, because the AC components have well defined standards, and AC technologies and products are already available in the market. However, DC-bus based system provides a more convenient way to integrate renewable energy sources and also higher energy efficiency thanks the inferior number of conversion stages.

IV. CONCLUSIONS

After a complete overview on different types of EV charging stations and a comparison between the related European and American Standards, the paper includes a summary on possible types of Energy Storage Systems (ESSs) and possible layout of charging stations including them. ESSs can become fundamental for the integration in smart grids of EV fast charging stations of the last generation: in this case the storage can have peak shaving and power quality functions and also to make the charge time shorter. From this brief analysis, it is possible to conclude that a good ESS for the coupling fast EV charging stations can be considered a system including batteries and ultra-capacitors: the first are suitable for their high energy densities and the second for their high power density. About the integration of ESSs, another important issue investigated is the way of integration in terms of electrical scheme. Two possibilities have been found in literature, based on an AC-bus configuration and DC-bus configuration. The AC-bus scheme is generally preferred, because the AC components have well defined standards, and AC technologies and products are already available in the market. However, DC-bus based system provides a more convenient way to integrate renewable energy sources and also higher energy efficiency thanks the inferior number of conversion stages.

ACKNOWLEDGMENT

This paper has been developed as a result of a mobility stay funded by the Erasmus Mundus Programme of the European Commission under the Transatlantic Partnership for Excellence in Engineering – TEE Project.

REFERENCES

[1] Facilitating e-mobility: EURELECTRIC views on charging infrastructure, EURELECTRIC Position Paper, March 2012.

[2] Piano nazionale infrastrutturale per la ricarica dei veicoli alimentati ad energia elettrica: testo per la consultazione pubblica, a cura del Ministero delle Infrastrutture e dei Trasporti, Dipartimento per le Infrastrutture, gli Affari Generali ed il Personale, Direzione Generale per lo Sviluppo del territorio, la programmazione ed progetti internazionali. 10 aprile 2013.

[3] G. Boulanger, A. Chu, S. Maxx, and D. Waltz, "Vehicle electrification: Status and issues," Proceedings of the IEEE, vol. 99, no. 6, pp. 1116–1138, 2011.

[4] O. Veneri, L. Ferraro, C. Capasso, D. Iannuzzi, "Charging Infrastructures for EV: Overview of Technologies and Issues", 2012 IEEE ESARS, Electrical Systems for Aircraft, Railway and Ship Propulsion Conference, Oct. 2012.

[5] M. Yilmaz, and Philip T. Krein, "Review of Charging Power Levels and Infrastructure for Plug-In Electric and Hybrid Vehicles", 2012 IEEE IEVC, International Electric Vehicle Conference, 4-8 March 2012.

[6] M. Brenna, M.C. Falvo, F. Foiadelli, L. Martirano, F. Massaro, D. Poli, and A. Vaccaro, "Challenges in energy systems for the smart-cities of the future". Proc. 2012 IEEE ENERGYCON, International Energy Conference and Exhibition, Florence, 9-12 Sept. 2012.

[7] M.C. Falvo, L. Martirano, D. Sbordone, and E. Bocci, "Technologies for Smart Grids: a brief review". Proc. IEEE EEEIC 2013, 12th Int. Conf. on Environment and Electrical Engineering.

[8] M.C. Falvo, L. Martirano, and D. Sbordone, "Microsystems for a Sustainable Energy Smart Grid". Springer Verlag Journal, Smart Innovation, Systems and Technologies 19 , Year 2013, pp. 259-269.

[9] M. Brenna, M.C. Falvo, F. Foiadelli, L. Martirano, and D. Poli, "Sustainable Energy Microsystem (SEM): preliminary energy analysis". Proc. 2012 IEEE ISGT, Innovative Smart Grid Technologies Conference.

[10] M.C. Falvo, L. Martirano, D. Sbordone, "D-STATCOM with Energy Storage System for Application in Smart Micro-Grids", Proceedings IEEE ICCEP 2013 International Conference on Clean Electrical Power. 11 - 13 June 2013. Alghero (Italy).

[11] P. Arboleya, I. Bertini, M. Coto, B. Di Pietra, M.C Falvo, L. Martirano C. Gonzalez-Moran, D. Sbordone, "ZERO Network-Impact Buildings and Smart Storage Systems in Micro-Grids", Proceedings IEEE EEEIC 2013. 13th International Conference on Environment and Electrical Engineering, Wroclaw, Polonies, 1 – 3 November 2013.

[12] M.C Falvo, L. Martirano, D. Sbordone, I. Bertini, B. Di Pietra, F. Vellucci, "A Flexible Customer Power Device for Energy Management in a Real Smart Micro-Grid", IEEE IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society, Wien, Austria. 11 - 13 November 2013.

[13] IEC 61851 Electric vehicle conductive charging system, 2010.

[14] A. Di Giorgio, F. Liberati, and S. Canale,"IEC 61851 compliant electric vehicle charging control in Smartgrids". Proc. IEEE MED13, 21st Mediterranean Conference on Control and Automation, Chania, GR, June 2013

[15] http:chademo.com/

[16] SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler, SAE J1772, Jan. 2010.

[17] Sae ground vehicle standards smart grid. SAE Taipei. Available: http://sae-taipei.org.tw/image/1283265726.pdf.

[18] A. Di Giorgio, F. Liberati, and S. Canale, "Optimal electric vehicles to grid power control for active demand services in distribution grids", 20th Mediterranean Conference on Control and Automation MED12, Barcelona, July 2012.

[19] L. P. Fernández; T. Gómez; R. Cossent, C. Domingo; P. Frías, "Assessment of the impact of plug-in electric vehicles on distribution networks," IEEE Transactions Power Syst., vol. 26 (1), pp. 206–213, Feb. 2011.

[20] M. Etezadi-Amoli; K. Choma; J. Stefani, "Rapid-Charge Electric-Vehicle Station," IEEE Transactions On Power Delivery, vol. 25 (3), July 2010.

[21] H. Hoimoja, A. Rufer, G. Dziechciaruk; A. Vezzini, "An Ultrafast EV Charging Station Demonstrator," International Symposium on Power Electronics, Electrical Drives, Automation and Motion, pp.1390-1395 June 2012

[22] D. Aggeler; F. Canales; H. Zelaya; A. Coccia; N. Butcher; O. Apeldoorn, "Ultra-Fast DC-Charge Infrastructures for EV Mobility and Future Smart Grids. Innovative," Smart Grid Technologies Conference Europe (ISGT Europe) IEEE PES, pp. 1-8, 11-13 Oct 2010.

[23] B. Sanzhong, Y. Du, S. Lukic, "Optimum design of an EV/PHEV charging station with DC bus and storage system," Energy Conversion Congress and Exposition IEEE ECCE, Atlanta, GA, USA 12-16 Sept. 2010, pp.1178-1184.

[24] G. Joos, M. de Freige, and M. Dubois, "Design and simulation of a fast charging station for PHEV/EV batteries, 2010 IEEE EPEC in Electric Power and Energy Conference.

[25] S. Bai, D. Yu, and S. Lukic, "Optimum design of an EV/PHEV charging station with dc bus and storage system", 2010 IEEE ECCE Energy Conversion Congress and Exposition.

[26] J. Song, A. Toliyat, D. Tuttle, and A. Kwasinski1, "A Rapid Charging Station with an Ultra-capacitor Energy Storage System for Plug-In Electrical Vehicles", in Electrical Machines and Systems (ICEMS), 2010 International Conference on, Oct. 2010, pp. 2003 –2007.

[27] I. S. Bayram, G. Michailidis, M. Devetsikiotis, B. Parkhideh, "Strategies for Competing Energy Storage Technologies for DC Fast Charging Stations", 2012 IEEE Third International Conference on Smart Grid Communications, SmartGridComm 2012